tion of vaccine in the laboratory, at some future time, when the work now in progress, has reached completion.

Bacteriological Laboratory, State Board of Health. Des Moines, Iowa, February, 1895.

Explanation of Plate XXIX.

Fig. 1. $\frac{1000}{1}$. *Dispora variolæ*, two days old growth in Pasteur's fluid.

Fig. 2. $\frac{1000}{1}$. Same; four days old. Specimen from surface film.

Fig. 3. ca. $\frac{1500}{1}$. Same; eight days old culture in bouillon. A few spore-bearing cells.

Fig. 4. ca. $\frac{1500}{1}$. Same; eleven days old culture in bouillon. Spore-bearing cells numerous.

Fig. 5. $\frac{1000}{1}$. Same; 25 days old bouillon-culture. Some free spores; chains.

Fig. 6. $\frac{600}{1}$. Same; one month old bouillon-culture. Cells almost disappeared; free spores in excessive numbers.

THE AFFINITIES OF THE LEPIDOPTEROUS WING.

By Vernon L. Kellogg.

It has long been recognized that the venation of the wings of the Trichoptera and Lepidoptera is of similar general character; and recognized, too, although less popularly, that the genera *Hepialus* and *Micropteryx* display more clearly than do any other lepidopterous forms this general resemblance to the trichopterous venation. Speyer,[1] in 1870, pointed this out in his discussion of the affinities of the Lepidoptera and the Phryganidæ. His too serious consideration of the many mere analogies apparent in any comparison of the groups did much

[1] Speyer, A. Ueber die Genealogie der Schmetterlinge, Stettiner Entomologische Zeitung, pp. 202–223, 1870.

to discredit the real points of worth brought out in his discussion. In the light, however, of the present association of *Hepialus* and *Micropteryx* as a sub-order, the *Jugatæ*, of the *Lepidoptera*, which is recognized as a distinctly more generalized group than the sub-order *Frenatæ*, which includes all other Lepidoptera, this trichopterous character of the jugate venation becomes more conspicuously significant.

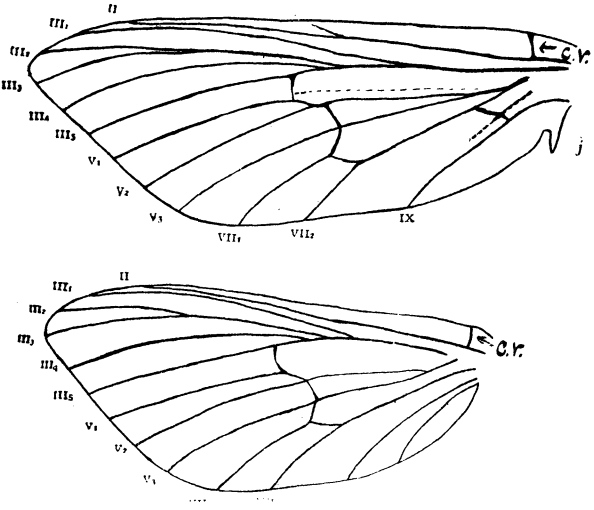

FIG 1 Wings of *Hepialus humuli*; *c. v.*, cross vein; *j*, jugum.

Hepialus[2] (see Fig. 1) and *Micropteryx* (see Fig. 2) are distinguished in point of venation[3] from the Frenatæ (see Fig. 3) by the fact that the radial area of the hind wings is not reduced, although the anal area is, thus causing a similarity in venation between the fore and hind wings, radius (III) being five-branched in each. This similarity of the venation of both wings is not to be found among the Frenatæ. The persist-

[2] The venational nomenclature used is that of Redtenbacher (Vergleichende Studien über das Flügelgeäder der Insekten, in Annalen der k. k. naturhistorischen Hofmuseums, Bd. I, 1886, Wien) adopted, with modifications, by Comstock.

[3] The real value of these taxonomic characters presented by the venation of the Lepidoptera can be fully appreciated after a reading of Prof. Comstock's essay on Evolution and Taxonomy; in the Wilder Quarter-Century Book, 1893, Ithaca, N. Y.

ence of the stem of media (V) anywhere among the Lepidoptera is an indication of a generalized condition, as is the persistence of more than two anal veins in the hind wings. At the base of the principal descent lines of moths are found generalized forms, their generalization indicated in their venation by the persistence of media (V) and often by the presence of three anal veins in the hind wings. But the specializing ten-

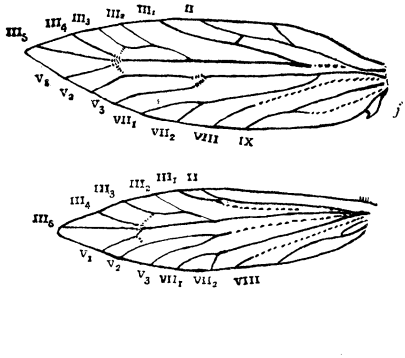

FIG. 2. Wings of *Micropteryx* sp.; *j*. jugum. (After Comstock).

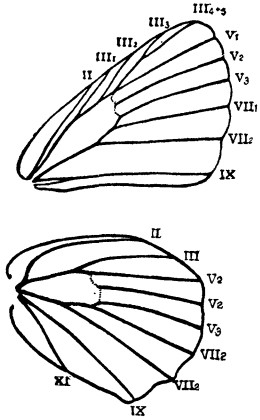

FIG. 3. Wings of *Chrysophanus thoe*. (After Comstock).

dency towards a cephalization of flight, resulting in a change from the racial sub-equality and importance of fore and hind wings to an inequality produced by a reduction of the hind wings has resulted in the loss (coalescence) among all living Lepidoptera, except the genera *Hepialus* and *Micropteryx*, of the branches of radius in the hind wings.

As pointed out by Prof. Comstock, the Jugatæ (*Hepialus* and *Micropteryx*) in this respect stand much nearer the racial lepidopteron than do any of the Frenatæ. The striking resemblance, then, of the jugate venation, standing, as it does, for the most generalized existing condition of lepidopterous venation, to the trichopterous type of venation is significant. By an inspection of the figures, herewith presented, of the venation of *Hepialus* (see Fig. 1) and *Micropteryx* (see Fig. 2) with those of the venation of *Neuronia* sp. (see Fig. 4) and of an undetermined

caddice-fly collected by me in Colorado (see Fig. 5), the reality of the correspondence is apparent. In the fore wings of all the simple unbranched sub-costa (II), the 5-branched radius (III_1–III_5), the persisting stem of media (V) coalescing at its base with cubitus (VII), the three branches (four in the Colorado trichopteron) of media (V), and the reduced anal field, are common characters. In the hind wings, the general character of the venational uniformity is only varied by differences which,

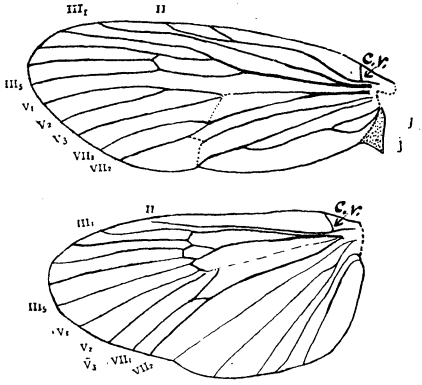

FIG. 4. Wings of *Neuronia*, sp.; *c. v.*, cross vein; *j.* jugum.

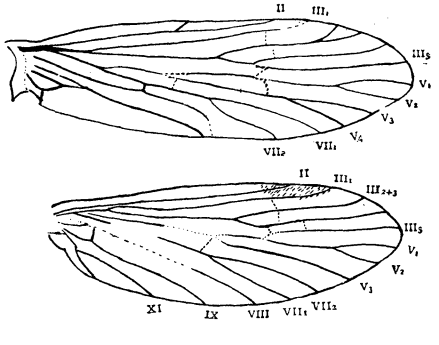

FIG. 5. Wings of undetermined caddice-fly; *j.* jugum.

in themselves, are additional evidences of a community of plan. One of the caddice-flies differs from the other in those correlated characters which have been pointed out by Prof. Comstock as characteristic of the tendency of specialization in the lepidopterous wing, viz., a tendency towards the coalescence (or disappearance) of the radial branches and increasing reduction of the anal area manifested by a loss of anal veins. In the hind wings of the Colorado caddice-fly (see Fig. 5) there are but four radial branches (III_1, $III_{2,3}$, and III_4 and III_5), and the anal veins (VIII, IX, XI, XIII), while two more in number than in *Micropteryx* or *Hepialus*, are less in number than in *Neuronia*.

It is beyond the scope of this paper to attempt any discussion of the lines of specialization exhibited by the wings of the Trichoptera, but it is an obvious and interesting fact that the

general characters of these lines are strikingly parallel with those exhibited by the Lepidoptera. A more primitive subequality of the wings, shown among the Lepidoptera only by the Jugatæ, is retained, but there is an obvious tendency towards a narrowing of the wings and consequent loss in number of veins, this loss being first apparent among the anal veins, and radial branches, and the hind wings being the first to be reduced. *Setodes* and other similar forms constitute an exception to this general tendency, something as do the Saturniina among the Lepidoptera, in that a peculiarly expanded anal field is displayed, although the venation of the wing is considerably specialized, the radial branches being largely reduced. The wing and anal area here are not in a primitive condition, but display a peculiar sidewise developed specialization. The tendency towards the disappearance of the base of media (V) is manifest, the stem of the vein in both fore and hind wings of *Mystacides punctatus* and others being represented by a mere fold.

Of interest in the comparison of the trichopterous and jugate wings, is the condition of the cross veins. The primitive neuropterous wings are characterized by the wealth of cross veins; the specialized lepidopterous wings are characterized by the almost total absence of these veins. The Jugatæ show more cross veins than do any of the Frenatæ. The usual trichopterous wings possess more cross veins than the jugate wing, but the manifest tendency is towards their fading out and disappearance. The wings of *Mystacides punctatus*, for example, a highly specialized trichopteron, shows fewer cross veins than do the wings of *Hepialus* or *Micropteryx*. In the hind wings of *Setodes* sp. there are no cross veins and but two or three in the fore wings. In the disappearance of the cross veins those midway between base and apex of wing persist longest; although there is a cross vein between the basal part of subcosta (II) and the costal margin of wing which is very persistent (see *c*.

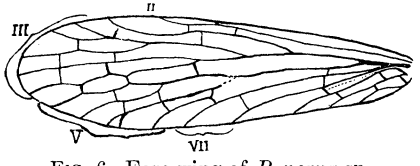

FIG. 6. Fore wing of *Panorpa* sp.

v. in *Hepialus humuli* Fig. 1, and in *Neuronia*, Fig. 4). I present a figure of the venation of the fore wing of *Panorpa* sp. which should be examined in connection with the jugate and trichopterous wings for the noting of this tendency of disappearance of the cross veins, and for the persistence of the mid-wing cross veins. It is worth while, in passing, to note also the general agreement in venational character of the mecopterous wing with the trichopterous and lepidopterous wings. The more generalized character of the *Panorpa* wing is manifest in the point of number of radial and medial branches and in the abundance of cross veins. As I have pointed out elsewhere, this disappearance of cross veins in these three groups proceeds coincidently with the development of the wing-scales, which serve to strengthen the wing-membrane.

Not alone in character of venation but in character of wing-clothing, as pointed out in a previous paper,[4] and in the mode of tying the fore and hind wings of each side together for the sake of sychronity of movement in flight, do the jugate and trichopterous wings show obvious resemblances. The well-known scale-hairs of the Trichoptera are simply the true lepidopterous scale in generalized state. Nor are these trichopterous scales always of so generalized condition as an examination of a limited number of wings might lead one to believe. There are many instances among the caddice-flies of the presence of well developed scales. In Fig. 7 well-specialized scales from the fore wings of two species of *Setodes* are shown at *c* and *d*. I have been specially interested to note in the wing clothing of *Mystacides punctatus* (see *a* and *b*, Fig. 7) in addition to the numerous broad scale hairs, a sprinkling of conspicuous large, flattened, bulbous, white scales, which present externally the peculiar characters of the variously modified scent-scales or androconia of the male butterflies.

The essential structural difference between the Jugatæ and Frenatæ on which the two groups were separated by Prof. Comstock is that displayed by the two methods of uniting the wings of each side during flight. The jugate moths have fore

[4] Author. The Classification of the Lepidoptera, AMERICAN NATURALIST, v. XXIX, no. 339, pp. 248–257, March, 1895.

and hind wings united by a membranous lobe, the jugum, borne at the base of the inner margin of the fore wings. When the wings of *Hepialus* or *Micropteryx* are extended, "the jugum projects back beneath the costal border of the hind wing, which, being overlapped by the more distal portion of the inner margin of the fore wing, is thus held between the two as in a vise." The frenate Lepidoptera have the two wings of each side united by the familiarly known frenulum borne at the base of the costal margin of the hind wings, or by a substitute for a frenulum, an expanded humeral area of the hind wings, by which a considerable overlapping of the wings is produced. The common occurrence of a jugum among caddice-flies (see *j* in Figs. 4 and 5), which is essentially the same structure presented by the jugate moths, has already been referred to by Prof. Comstock as of interesting significance. The jugate method is, however, by no means the only mode of wing union among the Trichoptera. The jugum may exist coincidently with other uniting structures, or it may be entirely wanting, the tying together of the fore and hind wings being accomplished by the overlapping for a considerable space of the hind margin of the fore wing and the costal margin of the hind wing, or by a row of hooks projecting from the costal margin of the hind wing which fasten to a chitinized ridge running along near the hind margin of the fore wing. There seems even to exist the beginnings of the frenate method of wing tying, as displayed in *Hallesus* sp. The wings of this trichopteron present a combination of the jugate and row-of-hooks methods of wing tying, and, in addition, there are present on the base of the costal margin of the hind wing two long strong hairs (see *f*, Fig. 8), the very counterpart of the generalized

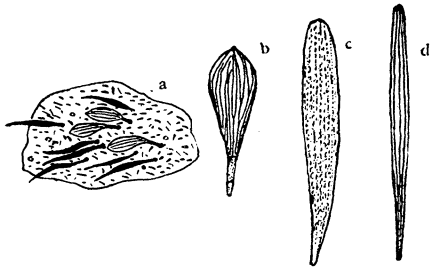

FIG. 7. Scales from wings of Trichoptera; *a*, portion of fore wing of *Mystacides punctatus* showing scale hairs and bulbous, androconia-like scales; *b*, one of the androconia enlarged; *c*, *d*, scales from fore wings of *Setodes*.

frenulum (i. e., frenulum in which the hairs are not united into one single strong spine) of the lepidopterous wing. This trichopterous frenulum is, however, much shorter than the lepidopterous frenulum and does not fit into a frenulum hook on the under surface of the fore wing, but merely rests against the jugum of the fore wing. The jugum is fairly well developed but can hardly overlap the base of the hind wing much. The series of tying hooks extends along the costal margin from near the base of the wing for about one-third the length of the margin. I have figured the method of wing tying for another species (see Fig. 9) which, however, illustrates the method and the functioning structures quite as truly for *Hallesus* sp. In the species figured, the hooks method, combined with the overlapping of the opposed margins of the wings, is the only means of union, the small, jugum-like structure at the base of the fore wing being practically functionless. When the wings are extended a narrow space along the inner margin of the fore wing, roughened on its under surface by many short, strong, sharp-pointed bristles, and with the membrane greatly strengthened and made less yielding by these bristles, is underlain by the costal margin of the hind wing for a distance of more than half the length of the margin. Along the extreme costal border of this underlying space, which is slightly expanded costal-wards, there is a regular series of strong, hooked hairs or bristles, each of which bears on the concave surface of the curved or hooked portion many fine teeth (see *c*, Fig. 9). These toothed hooks are applied to and firmly grasp a strong, roughened, chitinous line or ridge running along the under side of the fore wing. This chitinous line is roughened by the presence of fine ridges for the firmer grasping of the hooks. By the overlapping and hooking there is formed an effective tying together of the two wings.

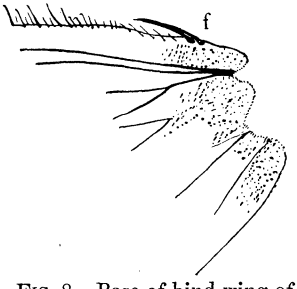

FIG. 8. Base of hind wing of *Hallesus* sp.; *f*, frenulum hairs.

This method of tying by hooks is a common one among the caddice-flies. Often there will be no chitinized ridge (chiefly produced by an extra thickening of one or more of the anal veins) for the hooks to grasp, but one of the anal veins will bear a series of stiff hairs or bristles which interlace with the hooked bristles and project in such a direction that they are effectually grasped by them. In connection with the hooks and slight overlapping of the wing margins, there is usually a well-developed jugum, which makes a firm overlapping connection between the bases of the wings. There are often, too, small bunches of strong, long hairs, or smaller number of still stronger hairs borne on the base of the costal margin of the fore wing, which project forward under the jugum, suggesting, as shown especially in *Hallesus*, the beginnings of the lepidopterous frenulum.

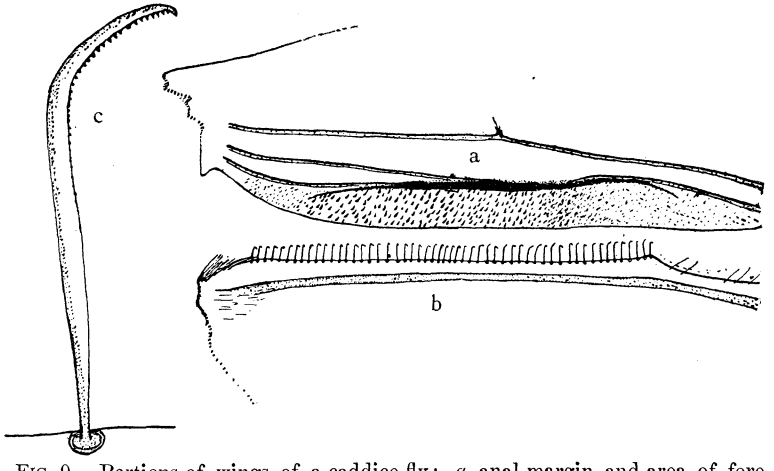

FIG. 9. Portions of wings of a caddice-fly; *a*, anal margin and area of fore wing; *b*, basal half of costal margin and area of hind wing; *c*, hook (enlarged) from costal margin of hind wing.

A most interesting wing tying arrangement is presented by *Panorpa* (see Fig. 10, *a*, *b*, *c*). We have here an arrangement which is strongly suggestive of what that racial type-structure may have been from which, on the one hand, the successfully functioning unaided jugum, and on the other, the perfected frenate arrangement could have been developed. The pretty

strongly developed jugum in this mecopterous form bears on its free margin four strong backward projecting bristles, while a basal expansion of the costal margin of the hind wing bears on its free margin four strong backward projecting bristles, while a basal expansion of the costal margin of the hind wing bears two long, strong, slightly diverging bristles, so projecting that one lies above the other. When the wings are expanded the four jugal bristles lie between two bristles of the hind wing (see *c*, Fig. 10), forming a unique tying arrangement.

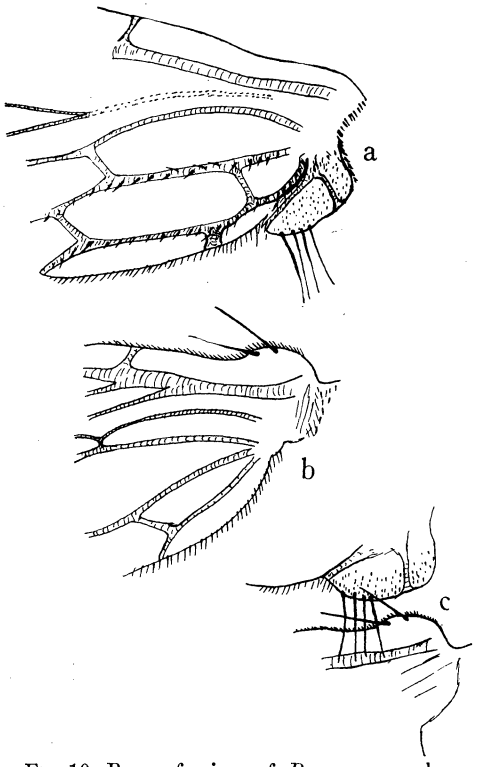

FIG. 10. Bases of wings of *Panorpa*; *a*, base of fore wing; *b*, base of hind wing; *c*, bases of both wings united.

So far as this organ is concerned, and for that matter, so far as concerns the venation and the wing clothing, the trichopterous wing, and the jugate and frenate types of the lepidopterous wing may all have had a generalized prototype very like the mecopterous wing. In the beginning the wings were independent and obviously the frenate type and the jugate type may have arisen, as suggested by Prof. Comstock, as distinct lines from the un-united wing type. But from the known phyletic relations of the Jugatæ and Frenatæ, and from the conditions presented by the trichopterous and mecopterous wings, which I have here attempted to indicate, the evidence, though as yet most ill-digisted, suggests strongly, to my mind, the probability of the

origin of the frenate type from an earlier type which was essentially jugate, but which possessed frenulum-like structures of a character to be easily developed, by selection, into the existing highly specialized frenate condition of the wings of the Noctuidæ and others.

In conclusion, I may add that every attempt I have yet made to study, in a comparative way, the morphology of the three insect groups mentioned in this paper, has afforded in each succeeding instance stronger basis for a belief in the close phyletic relationship of the groups, a belief shared with, of course, and already expressed by many others.

Stanford University, Calif.

ON THE PRESENCE OF FLUORINE AS A TEST FOR THE FOSSILIZATION OF ANIMAL BONES.

By Dr. Thomas Wilson.

(*Continued from page 456, Vol. XXIX*).

Appreciating the importance of the discoveries made in France in regard to the proportion of fluorine in animal bones as a test of their fossilization and antiquity, I determined to make a further attempt in the investigation by analysis of the bones, human and mylodon, found by Dr. Dickeson at Natchez, as heretofore described (page 303). To that end, I made application to Dr. Samuel G. Dixon, Curator of the Academy of Natural Sciences of Philadelphia, for specimens of the two bones to be subjected to analysis with a view to the determination of their respective proportions of fluorine. Dr. Dixon kindly presented my application, and it was allowed. In due course I received the fragments from the two respective bones. Professor R. L. Packard was engaged in the laboratory in the U. S. National Museum making a series of mineral and rock analyses, we had, together, become acquainted with Mons. Car-